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HULL FOULING

by

Richard J. Stenson

[redacted]

HYDROMECHANICS LABORATORY

RESEARCH AND DEVELOPMENT REPORT

July 1967

Report 2509

HULL FOULING

The Naval Ship Research and Development Center is a U.S. Navy center for laboratory effort directed at achieving improved sea and air vehicles. It was formed in March 1967 by merging the David Taylor Model Basin at Carderock, Maryland and the Marine Engineering Laboratory at Annapolis, Maryland.

Naval Ship Research and Development Center
Washington, D. C. 20007

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ABSTRACT

This report contains the results of an investigation conducted by the Naval Ship Research and Development Center (formerly David Taylor Model Basin) concerning the effects of hull fouling encountered during various full-scale trials. Measurements were made to determine the increase in powering requirements as days out of drydock increased. Data are presented for two frigates, a destroyer division, and a submarine.

ADMINISTRATIVE INFORMATION

The research on effects of hull fouling was authorized by Bureau of Ships letter SF-0130207, Task 1713, Serial 436-355, of 29 November 1965.

INTRODUCTION

PURPOSE

There are recurring complaints from the forces afloat concerning the loss of speed and consequential additional powering requirements that occur as time out of drydock increases. In most cases, the complainants blame machinery performance of their vessels. This paper is issued to emphasize to ship operators the magnitude of the harmful effect of hull fouling on ship speed and powering requirements. No attempt is made to arrive at a hard and fast rule for calculating the effects of hull fouling as time out of dock increases; the variables involved would require a complete day-by-day service history of the individual vessel. Instead, types and severity of fouling are described and examples of hull fouling encountered by the Naval Ship Research and Development Center (formerly David Taylor Model Basin) during full-scale trials are presented.

BACKGROUND

As a ship moves through water, its resistance is composed of two major components, frictional resistance and residual resistance. Frictional resistance occurs as frictional forces are set up by the flow of water along the hull surface and therefore it is affected by the surface texture of the hull. On the other hand, residual resistance is caused by pressures built up to push the water aside and it is mainly influenced by hull shape. The percentage of the total resistance which is frictional, and the percentage which is residual, will vary with speed. Frictional resistance will comprise a larger portion of the total resistance at low speed length ratios.

Since frictional resistance is affected by hull surface, it is directly influenced by hull fouling and the surface coatings used to prevent this fouling. Recognition of this influence is attested by the fact that for design purposes, the British Admiralty allows for an increase of frictional resistance of 0.25 per cent per day out of dock in temperate waters and up to 0.50 per cent per day in tropical waters.[1]

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[1] References are listed on page 14.

DESCRIPTION OF HULL FOULING

TYPES OF FOULING

There are two main types of fouling. The first occurs immediately upon the undocking of the vessel and its subsequent immersion in salt water. This type consists mainly of soft slimes of a gelatinous nature, with no real solid matter, and is usually of uniform thickness. This fouling develops frictional drag immediately and increases in amount until its effect is taken over by fouling of the second kind. The second type consists of rigid coatings such as grasses, marine vegetation, shells, and barnacles. When this type of fouling takes hold, a noticeable increase in resistance occurs. The overall result, then, is a nonlinear increase in resistance with time out of dock; the moderate rise in resistance that occurs immediately after undocking is followed by a slow additional increase for an intermediate period of from 2 to 4 months, and then by a significant increase when fouling of the second type sets in. Saunders in Reference 2 states that "If a ship is left moored or at anchor to accumulate marine growths having thicknesses of inches or even feet, $\Delta_F C_F$ (the resistance due to fouling) probably reaches a maximum value by the time the hull surface is completely covered with a growth 0.1 to 0.2 feet thick. It may not become larger no matter how dense or thick the growth." The additional weight displacement and volume displacement due to heavy fouling will require additional power over and above that due to the fouling alone. Saunders also states that "Ships have been known to pick up from 100 to 300 tons of marine growth when heavily fouled."

SEVERITY OF FOULING

The factors involving the severity of fouling are many and varied. Fouling is most severe in tropical waters, where its growth is rapid and uninterrupted by seasonal variations. It is more cyclical in temperate latitudes occurring heavily during summer months and less during the colder months. It occurs in fresh water only as a slight slime around the boot-topping of a vessel. It has been long known that fouling can be arrested by moving from salt water to fresh water, but such practice generally will not lessen or eliminate fouling which has already occurred. Fouling grows most rapidly on ships that are at anchor or moving slowly. Fouling decreases as the speed of a ship increases because it is less able to attach itself to hull surfaces of a fast moving vessel and because some growth will be washed off by the fast moving water. To establish a fouling rate for a particular ship would require including such variables as type of antifouling coat applied, the time elapsed since application, the speed of the ship, the area of operation, the characteristics of the water, and the seasonal variations to be expected.

EXAMPLES OF HULL FOULING

GUIDED MISSILE FRIGATES

Figure 1 compares three trials conducted by the Center on frigate No. 1 which had been painted with the standard Navy vinyl resin antifouling paint.

The first trial was a Naval Ship Systems Command standardization trial conducted after the ship had been waterborne some 96 days; see Curve A of Figure 1. After an extended period of duty, it was determined that the ship was no longer able to attain rated rpm without overpowering. A second set of trials was then authorized to determine the cause of this problem. These trials (Curve B of Figure 1) showed an average increase of 12 per cent of clean hull shaft horsepower throughout the speed range and as much as 10 per cent at the maximum attainable rpm. There was a corresponding decrease in maximum speed of 7 rpm or approximately 0.6 knot. This increase in horsepower and loss of rpm prompted a decision to drydock the vessel for a complete cleaning and refinishing of the hull. Figure 2 shows the condition of the hull and propeller at this drydocking.

The ship was then sandblasted and completely repainted with the same antifouling vinyl system. Post repair trials were then conducted to determine the effects of this hull cleaning. The circled data points (⊙) in Figure 1 show the results. Note that they fall on the original standardization curve (Curve A), indicating that the horsepower increase previously reported was directly attributable to hull and propeller fouling.

Figure 3 shows a similar set of trials conducted on frigate No. 2 with a hot plastic paint system. Curve A, the standardization curve for this class ship, was conducted 29 days after leaving drydock. Curve B is a full-power trial which was run 732 days out of drydock. The increased powering requirements are quite evident in this Figure, with an average increase of approximately 9 per cent of clean hull shaft horsepower throughout the speed range, and as much as 8 per cent at the maximum attainable rpm.

Figure 4 is a comparison of the fouling rates of these two frigates and shows the percentage increase in powering requirements at various percentages of full-power rpm. The vinyl resin paint can be seen to have fouled more rapidly, although out of dock some 100 days less than the hot plastic system.

DESTROYERS

The Center also conducted a series of tests on a destroyer division[3] to determine the effects of hull fouling on vinyl resin and hot plastic paints currently used by the Navy. Four ships of the same class were selected for trials and all four were painted with a base of zinc chromate. They were initially standardized in this condition as soon as practicable after leaving drydock in order to determine the basic structural roughness of the hull. Results were essentially identical for the four ships.

Two destroyers were then coated with vinyl resin and two with hot plastic. In no case was a ship more than 5 days out of drydock at the time of its first trials with antifouling paint. The initial test results with similar antifouling paints were identical within test accuracies. Ships coated with hot plastic gave a considerably greater initial resistance than did those with vinyl resin paint, but the latter had a higher fouling rate.

The ships were restandardized at two 6-month intervals up to a total of 670 days out of dock. In all, then, the Center had data on four comparative trials for each ship. A day-by-day history of the operational commitments of each ship was also maintained.

Figure 5 shows percentage increase in shaft horsepower, thrust, torque, and rpm versus days out of drydock at three different speeds for the hot plastic type of antifouling paint. Figure 6 gives similar data for the vinyl resin paint system. Comparison of the two plots indicates that the vinyl resin had a higher fouling rate than the hot plastic and resulted in a greater percentage increase in horsepower, thrust, torque, and rpm. It should be recalled, however, that the initial resistance of the hot plastic was higher. Thus, even with a greater fouling rate, the resistance of the ships coated with vinyl resin never exceeded that of the ships coated with hot plastic.

Figure 7 compares speed and rpm with time out of drydock for two of the ships, one with vinyl resin and one with the hot plastic system. The curves show rather well the effects of fouling. After 660 days out of dock, the hot plastic-coated ship had a decrease in speed of 0.75 knot and an increase of 4 rpm was required to develop full speed. Corresponding values for the vinyl resin-coated ship were 1 knot and 4.5 rpm.

SUBMARINE

In the course of standardizing an experimental submarine, the Center has another example of the effects of hull fouling. The submarine was painted with a vinyl resin system and originally standardized at the measured mile course at Provincetown, Massachusetts, on 30 April 1965. At the time of trials, she had been out of dock some 105 days; however, all of this time was spent in northern waters. Curves A and B of Figure 8 are plots of percentages of speed and horsepower for the surfaced and periscope conditions in this series of tests.

The submarine was then operated in an area of high marine growth for several months. During this period, her home port was Key West, Florida. When this submarine returned directly to Provincetown in late July, her hull was quite badly fouled. An additional standardization trial was conducted on 31 July 1965, some 201 days out of drydock. This second set of trials (Curves C and D of Figure 8) shows an increase in horsepower requirements of some 30 per cent for the surfaced condition and 28 per cent for the periscope condition.

CONCLUSION

The examples cited typify the effects of fouling which can be expected in present day naval vessels. The vinyl resin and hot plastic systems currently used as antifouling paints are a vast improvement over the hull coatings of the past; however, they are still subject to fouling as these examples have shown.

It should be borne in mind that although greatly reduced in the last few years, the effects of hull fouling on the speed and power of vessels is still a factor to be reckoned with for naval vessels of all types.

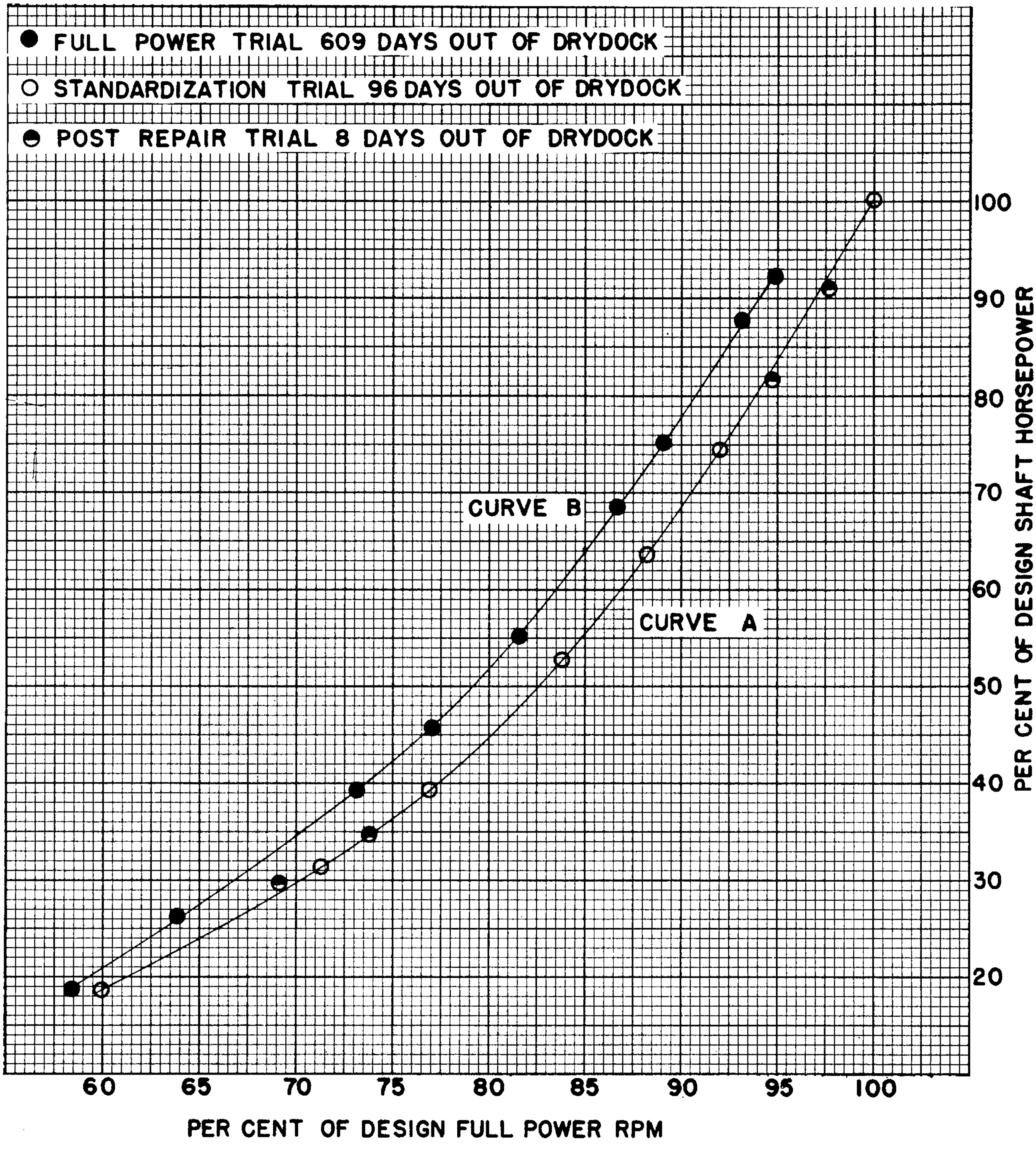

Figure 1 - Effects of Fouling on Shaft Horsepower for Frigate No. 1

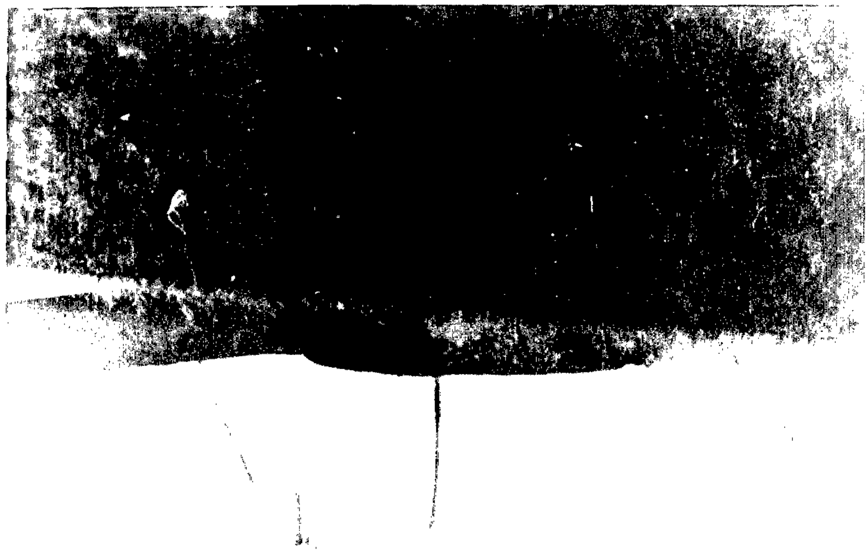

Figure 2a - Hull Fouling

Figure 2b - Propeller Fouling

Figure 2 - Fouling of Frigate No. 1 610 Days Since Last Docking

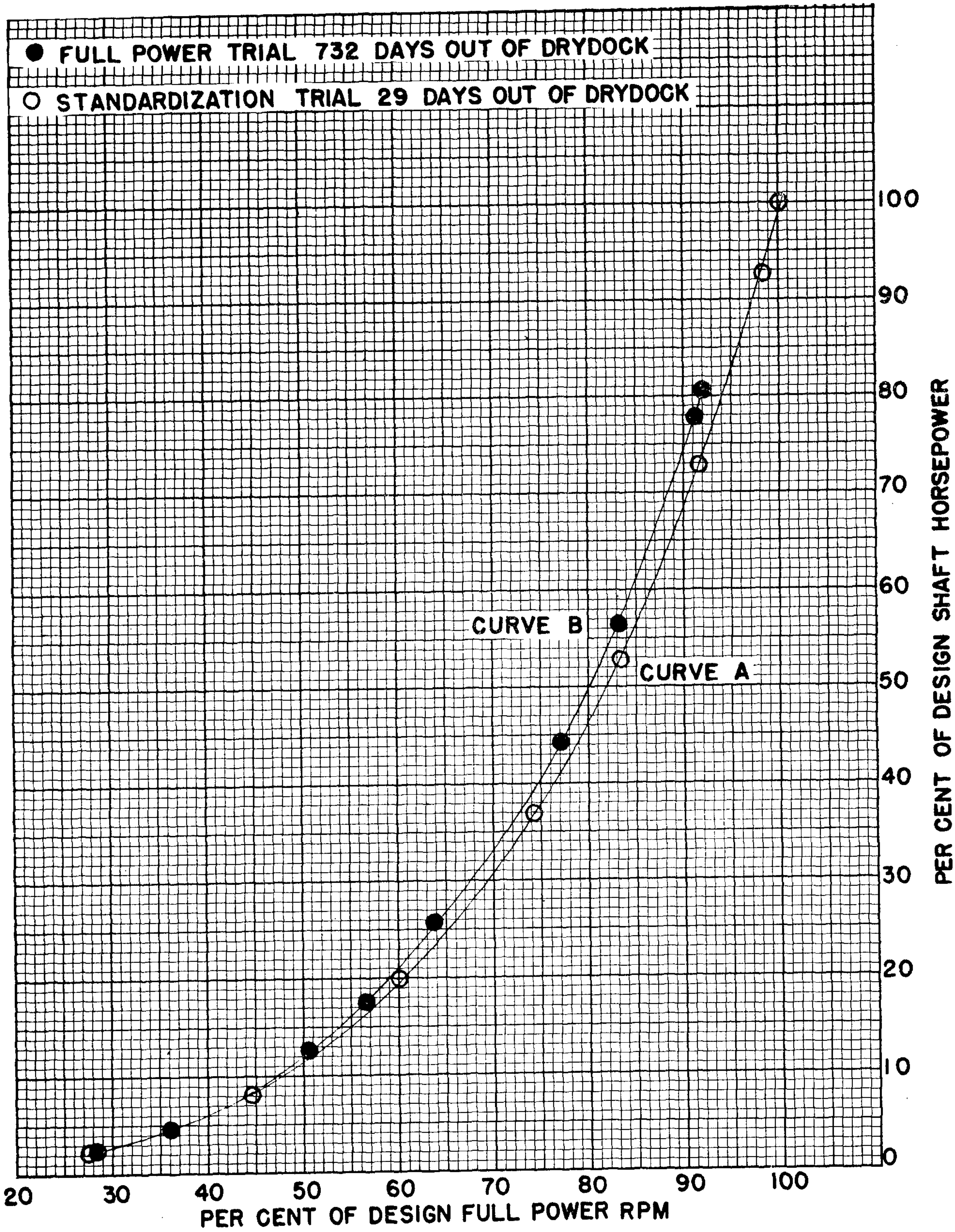

Figure 3 - Effects of Fouling on Shaft Horsepower for Frigate No. 2

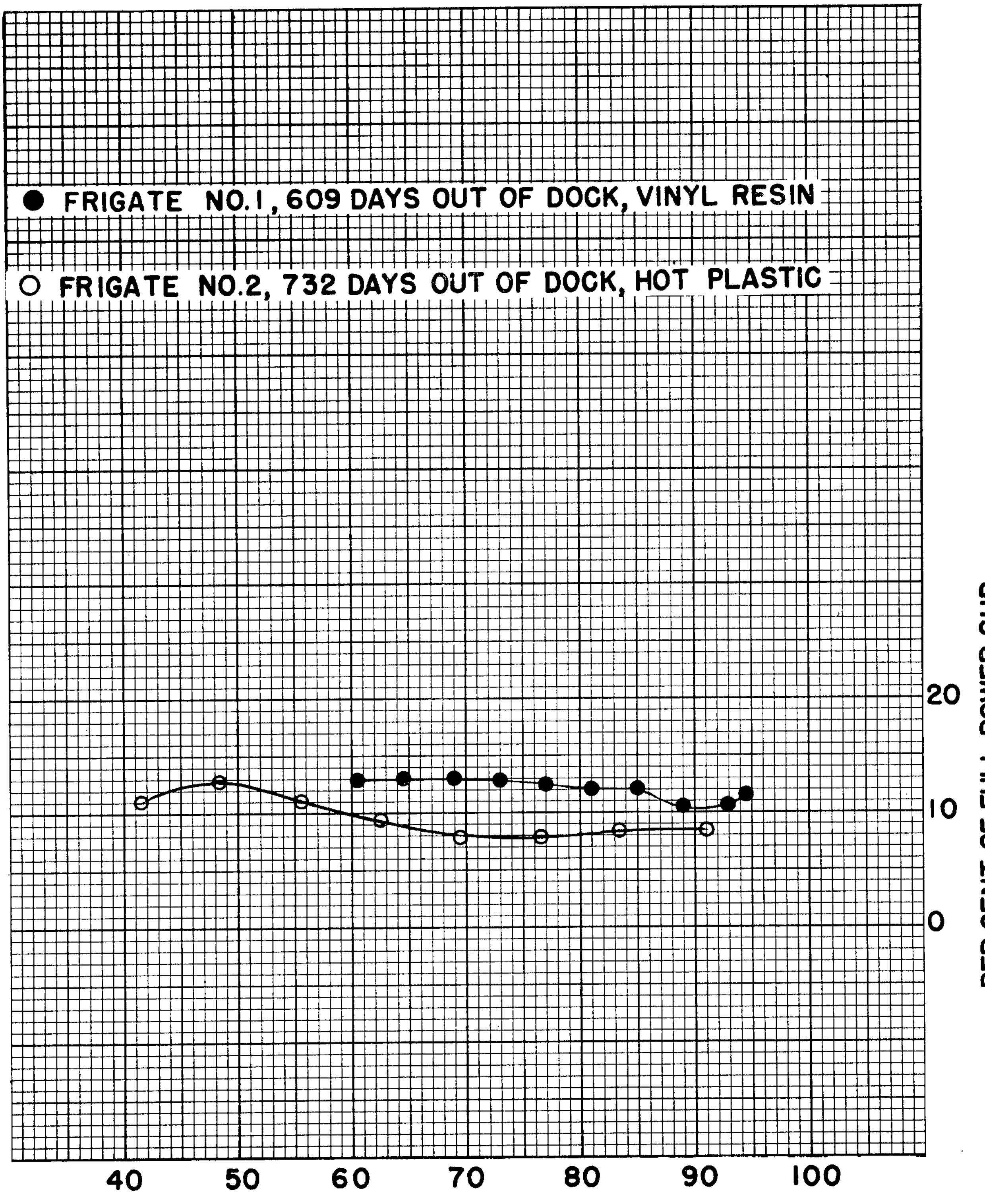

Figure 4 - Percentage Increase in Power for Frigates No. 1 and No. 2

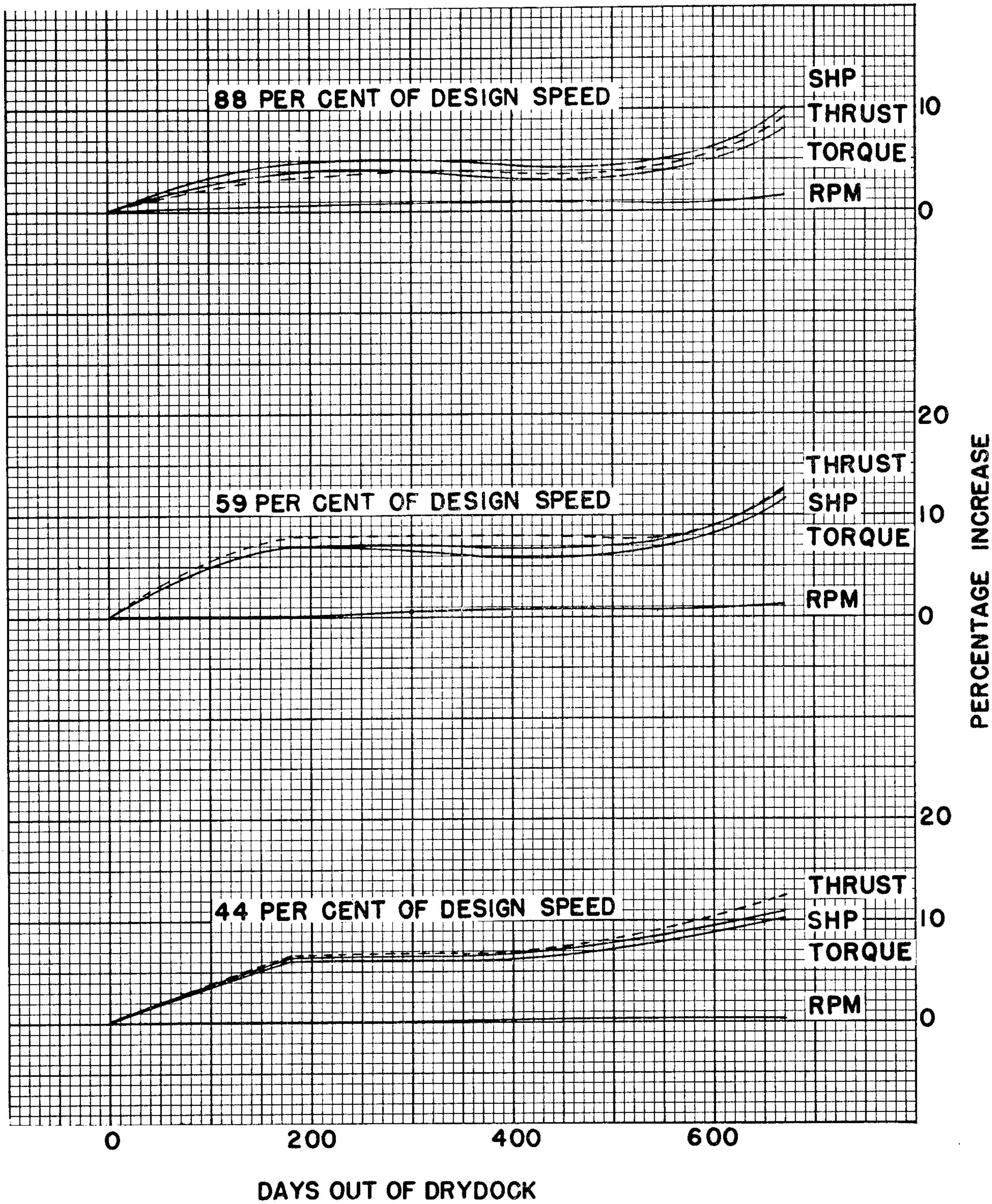

Figure 5 - Increased Powering Requirements versus Time out of Drydock for Destroyer Hull Painted with Hot Plastic

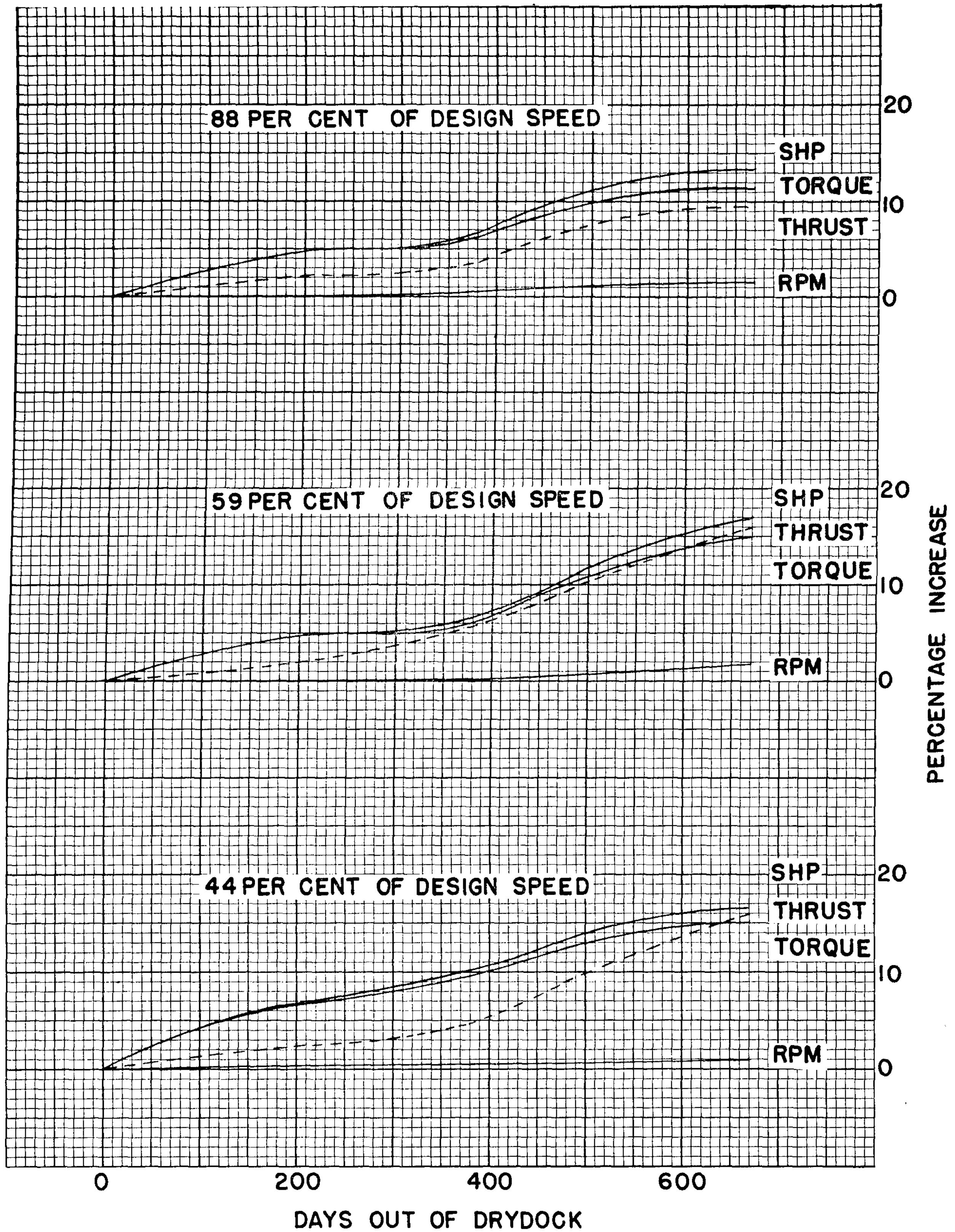

Figure 6 - Increased Powering Requirements versus Time out of Drydock for Destroyer Hull Painted with Vinyl Resin

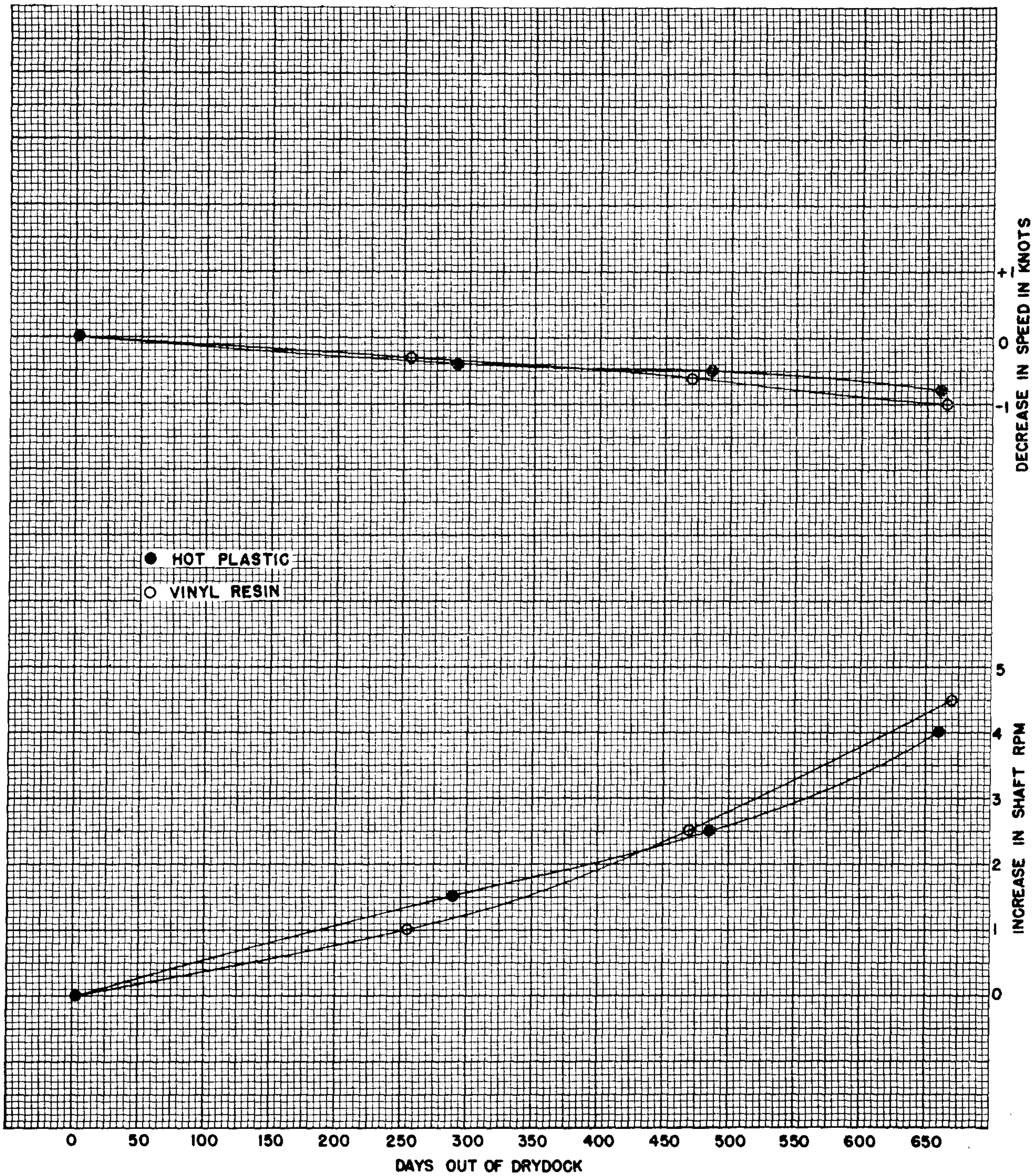

Figure 7 - Speed and RPM versus Time out of Drydock for Destroyers Protected by Vinyl Resin and Hot Plastic Paints

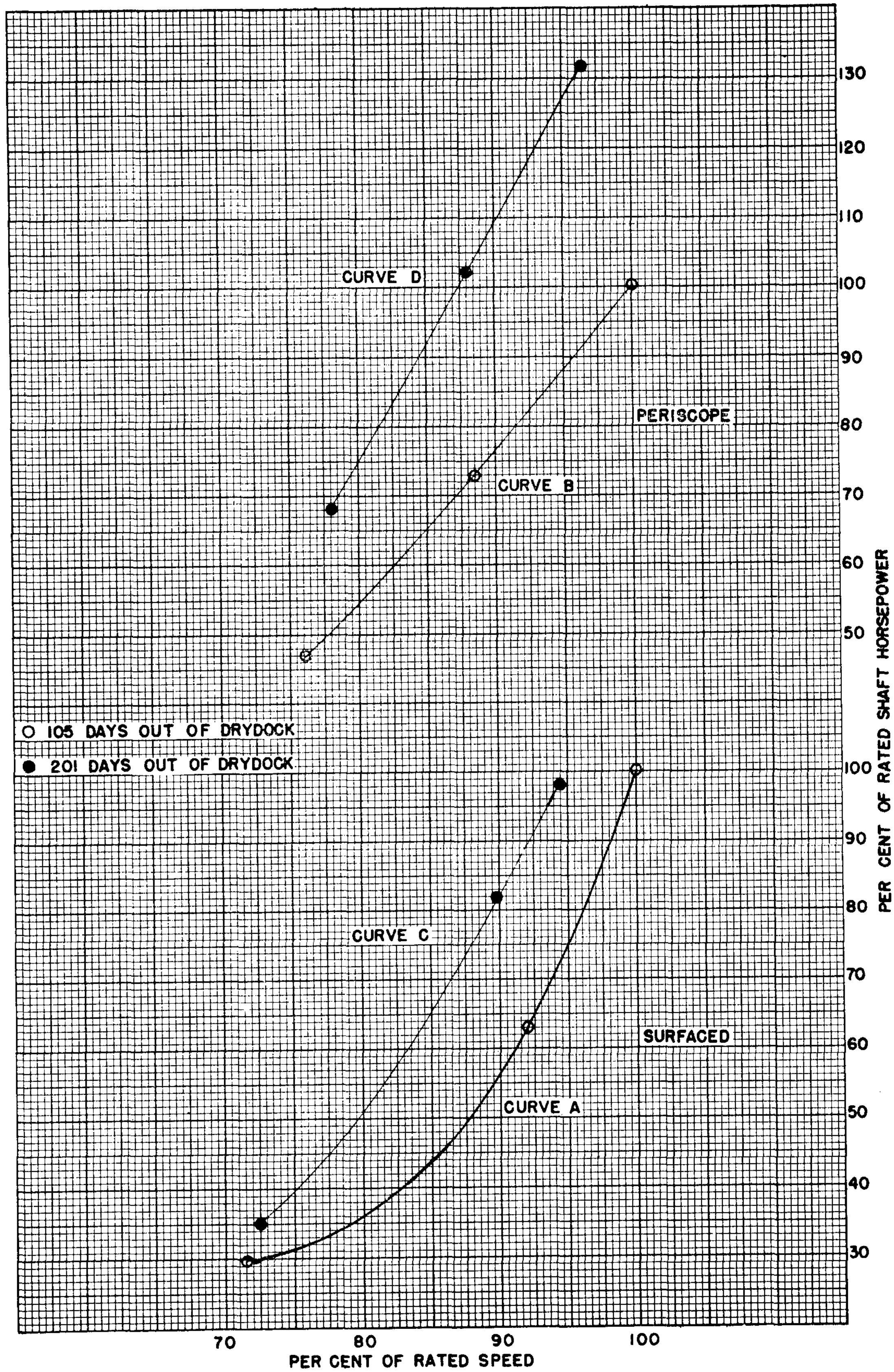

Figure 8 - Increased Powering Requirements versus Time out of Drydock for Surfaced and Periscope Conditions of a Submarine

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1. Woods Hole Oceanographic Institution, "Marine Fouling and Its Prevention," (1952).

2. Saunders, H.E., "Hydrodyanmics in Ship Design," The Society of Naval Architects and Marine Engineers, Volume Two (1957).

3. Hadler, J.B. et al, "Ship Standardization Trial Performance and Correlation with Model Predictions," 1962 Transactions of The Society of Naval Architects and Marine Engineers, Volume 70.

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2. Frigates--Resistance--Trials
3. Destroyers--Fouling--Power output--Requirements
4. Destroyers--Resistance--Trials
5. Submarines--Fouling--Power output--Requirements
6. Submarines--Resistance--Trials
7. Ship hulls--Fouling--Prevention
8. Ship hulls--Coatings--Effectiveness

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